

Technical Studies on Materials from Yayoi Period Japan: Their Role in Archaeological Interpretation

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THIS PAPER attempts to explore the relationship between a rising interest in technical studies on archaeological materials and archaeological interpretation as seen in the study of Yayoi culture in Japan, the so-called Bronze-Iron Age, which is dated 300 B.C. to A.D. 300.

Archaeologists in Japan as elsewhere have long focused their attention on the morphological properties of artifacts. However, with interest turning increasingly toward questions of prehistoric economy, technology, warfare, settlement, social organization, and religion, the role of the natural sciences in archaeological interpretation is becoming substantially more significant. For example, scientific procedures and techniques are necessary in order to examine such questions as the nature and sources of raw materials, techniques of artifact manufacture, and the uses to which the finished objects were put. Scientific techniques aid the archaeologist in four basic areas: (1) to establish absolute and relative chronology at sites; (2) to reconstruct the environment which prevailed at the time of site occupation; (3) to learn more about the biological aspects of the site occupants; and (4) to abstract more information from the material cultural remains discovered in sites.

In what ways is this information of use to the archaeologist? As Sherlock Holmes is reported to have advised all would-be detectives: "Don't seek to grasp at answers; Seek to ask the right questions." His message could also have been directed at archaeologists. The information from technical studies in the four areas outlined above may lead the archaeologist to pose more and better questions of his data and

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thereby possibly suggest hypotheses for testing against his archaeological data in an effort to arrive at some sort of explanation of the data. What has been the effect of technical studies on archaeological interpretation of Yayoi period Japan? The evidence will be examined in each of the four basic areas.

1. DATING

While radiocarbon dating has been of great importance to cultural interpretation in some areas of East Asia, as is well demonstrated by the appearance of the first radiocarbon dates from the People's Republic of China, its applications at Yayoi period sites have been of rather more limited significance. Only a comparatively small number of radiocarbon dates are available for Yayoi sites. A number of Japanese archaeologists dismiss radiocarbon dating as having too wide a time-error margin to be of much use for establishing datings within a period which is thought to be only about six hundred years in duration (Sugihara 1972: 5). This method has been useful for establishing general temporal parameters for the Early, Middle, and Late Yayoi periods, each of which was arbitrarily given a two-hundred year time span (Morlan 1967: 195) and correlated with ceramic styles which have been subjected to the same intensive typological ordering accorded Jōmon period ceramics. Japanese archaeologists by and large feel that cross-cultural dating, using such items as Chinese coins and Han dynasty mirrors, is a more useful dating method for the Yayoi period. The shortcomings of the use of such items for deriving chronology are obvious; to measure the time which elapsed between their manufacture in China and their appearance in Japan is extremely difficult, particularly in view of the poor state of knowledge about the Bronze-Iron Age of the Korean peninsula through which these items are believed to have traveled en route to Japan.

Better chronological control in absolute terms may be achieved for this period with the use of thermoluminescence dating. In addition, if radiocarbon dating were done for a great number of Yayoi sites and these dates carefully examined in light of the associated cultural remains, especially ceramic chronologies, archaeologists could deal with questions such as the rate of diffusion of the culture eastward from its place of origin in North Kyushu.

2. ENVIRONMENT

The second area in which the natural sciences have provided significant findings is environmental reconstruction, primarily through the analyses of soils and animal and plant remains.

The Yayoi period marks the initial appearance of paddy rice cultivation, the lowland, wet-field cultivation of rice, in Japan. Recent evidence suggests upland, dry-field cultivation of rice and barley in Late and Final Jōmon times (Kotani 1972: 258). Evidence of this nature is still very limited, but increasing use of flotation analysis and palynology may provide greater substantiation for Jōmon cultivation. In attempting to locate rice-growing areas in prehistoric times, Hachiga (Sahara and Kanaseki, personal communication, 1973) has examined distribution maps of soils. He found that peat soils covered by water are the poorest for rice cultivation. Because lowland marshy areas are thought by archaeologists such as Kondo (1966) to have been used for the sowing of rice seeds in the early part of the

Yayoi period, Hachiga has concluded that rice yields must have been very low, a suggestion borne out in the evidence for the continuation of hunting, fishing, and gathering practices at Yayoi sites, particularly in the Early Yayoi period. Confirmation of the lowland situation of Yayoi sites as well as the continuation of Jōmon economic practices is provided by virtually all of the Early Yayoi settlement sites beginning with the Itazuke site in Fukuoka City, the type site for the Itazuke phase which is the earliest phase of Yayoi culture, as well as a number of the later sites from this period. The presence of drainage ditches at sites such as Itazuke suggests possible attempts at water control.

The examination of plant and animal remains at sites is now beginning to attract sufficient research attention to make possible some general statements on paleo-environmental conditions. From some Yayoi sites where such materials were found preserved and collected in the course of the excavation, fairly detailed information is available. Flotation analysis of plant remains, although only a relatively recent introduction in Japan, is being carried out with increasing frequency at sites. Other research methods have also provided useful results. In this regard, spodographic analysis is an interesting example. The procedure for spodographic analysis or the study of phytoliths is to extract silica bodies either from soils or ashes at the site and then, on the basis of the silica characteristics, to identify them at the genus level under a microscope. The principle behind this method is that when a plant is burned in air, the organic portions of the plant are lost but the inorganic portions of the plant remain in the form of ash. If the burning temperature is below the melting point of the inorganic substance, the ash will show under microscopic magnification some of the features of the original plant material after being subjected to a 10 percent solution of hydrochloric acid (Watanabe 1968: 217). This technique was applied by Watanabe to samples from two different layers of the Nishishiga shell midden, the site which marks the most easterly extent of Yayoi culture during the Early Yayoi period. He found that the first sample of ash remains consisted almost totally of phytoliths of rice and that the second sample very closely resembled the first in the botanical characteristics of the phytoliths (Watanabe 1968: 224-225). Because the Nishishiga site has yielded carbonized rice grains and rice hull impressions in pottery and is radiocarbon dated at 2520 ± 140 B.P., 2220 ± 120 B.P., and 2440 ± 130 B.P. (Morlan 1967: 195), it appears that rice was in existence in the Nagoya area in Early Yayoi times, a conclusion further borne out by the associated Early Yayoi Ongagawa style ceramics (Sumita 1955: 98). Watanabe also tested his method at the Kameyama site, a Late Yayoi site in Tokyo, as well as at several Kofun and historic period sites where other forms of evidence for the existence of paddy rice cultivation were present. Of the other cereal grains, only millet has been identified using this method. Carbonized millet has been reported from a very few Yayoi period sites, including Tateiwa, situated to the east of Fukuoka City, and the Ayaragi and Okahara sites, both in Yamaguchi Prefecture. In his report on spodographic analyses of samples from the Tateiwa site, Watanabe (1970: 357-379) concludes that silica bodies characteristic of the millet species *Setaria italica* Beauv. were present. However, it should be noted that this method does have limitations in that all cultivated cereal grains belong to the Gramineae family, which contains a great number of species. Hence, identification may be very difficult in some cases. The identification of Gramineae species in Japan was undertaken by Nakamura,

who compiled a chart in 1970 indicating size range of equatorial diameters and polar lengths on the basis of his examination of 182 species of modern Gramineae pollen grains. He found that most of the wild grasses had both equatorial and polar diameters of 50 microns, thereby indicating the apparent difficulty in differentiating wild and cultivated grass pollen grains on the basis of diameters only. However, Kotani (1972b: 82) notes that it is possible using these criteria to distinguish roughly such genera as *Triticum*, *Hordeum*, *Zea*, *Avena*, *Coix*, and *Secale*. Palynological research has been carried out at only a small number of Yayoi sites. At the Itazuke site three samples were taken from ditches; two are given Early Yayoi datings and one a Middle and Late Yayoi date on the basis of associated cultural remains. The Early Yayoi pollen samples contained large quantities of *Triticum sativum* var. *vulgare* (wheat) and less than 1 percent rice pollen (*Oryza sativa* Linne). The Middle to Late Yayoi sample contained no wheat pollen but did contain over 10 percent rice pollen (Fukuoka City Board of Education 1970: 29). However, it should be noted that pollen is fairly easily transferred; hence the presence of carbonized rice grains and rice hull impressions in pottery as well as many wooden agricultural tools and semilunar stone reaping knives and the Early Yayoi paddy field posts discovered in 1972 are important corroborative evidence.

Yayoi research is now seeing a much increased interest in the identification of plant remains at sites. A picture of the types of plants gathered and cultivated by Yayoi Man is beginning to emerge through work such as that of Kawagoe (1970: 40), in which he reports that rice, wheat, millet, barnyard millet, pasania nuts, horse chestnuts, and red India beans were discovered at Yayoi sites along the western end of the Inland Sea. Faunal remains are also being viewed with renewed interest, especially in terms of determining the role played by the continuation of hunting, gathering, and fishing practices in Yayoi times when the cultivation of paddy rice and other cereal grains was providing an increasingly larger proportion of the overall subsistence base. However, preservation conditions often are quite poor, and investigation such as that at the Itazuke site, where clam, oyster, and Japanese carpet shell as well as wild boar, deer, and fish bone were identified (Fukuoka City Board of Education 1970: 5-6), and at the Takahashi shell midden, an Early Yayoi site in Kagoshima Prefecture where thirty-seven seawater varieties of shellfish were identified (Kawaguchi 1965: 105), is comparatively rare in the literature.

Further insight into the diet of the inhabitants of Yayoi period sites could be gained from the examination of coprolites, the first of which in Japan were identified several years ago (Sahara, personal communication, 1973). In addition, the examination of residues from cooking vessels, the straight-sided jars termed *kame* in Japanese, might also prove useful.

3. HUMAN BIOLOGY

Research in the third area, the human biology of the inhabitants of Yayoi period sites, has been quite limited, largely because conditions for preservation in the primarily acidic soils present at many Yayoi and other archaeological sites have not allowed the preservation of skeletal remains. However, preservation conditions have been good in some cases, perhaps best illustrated by the large Early Yayoi cemeteries at Doigahama, where more than 150 individuals were discovered (Kanaseki, Tsuboi, and Kanaseki 1972), and at Nakanohama, which is estimated to be several

times larger than Doigahama (Kanaseki, personal communication, 1975). At these large Yamaguchi Prefecture cemeteries, the soils contain relatively high percentages of pulverized shell, resulting in more alkaline soil conditions which favor the preservation of bone. Ageing and sexing of skeletal remains have usually been carried out where conditions of the remains have permitted such investigation.

Some scholars have attempted to postulate a large-scale migration to Japan around the beginning of the Yayoi period to help account for the appearance of the continentally-derived cultural elements which start to appear at this time; however, research by physical anthropologists has shown little support for this contention. Naito (1971: 236-248) compared skeletal remains from several Yayoi sites in northwestern Kyushu and those from the Mitsu site, Fukuoka Prefecture, and the Doigahama site with Jōmon remains from the Tsugumo site, Okayama Prefecture. He found that the northwestern Kyushu Yayoi and Tsugumo Jōmon remains were relatively similar for both sexes in all facial measurements and indices, while Mitsu and Doigahama skulls had larger average facial and upper facial indices. In terms of average main calvarial measurements and indices for both sexes, all skulls were very similar. Naito reports that the Yayoi skeletons from northwestern Kyushu of both sexes were similar in stature to Jōmon ones; both of these groups were shorter than the Yayoi period individuals from Mitsu and Doigahama. Nagai and Sano (1968: 175) concluded that individuals from Doigahama, Mitsu, and Koura, the latter a Yayoi cemetery on the Sanin coast of western Honshu, could be grouped together as a single regional type while skeletal remains from the Hirota site on Tanegashima, off the south coast of Kyushu, had smaller skulls and shorter statures (154.7 cm); heights for the former group were calculated to have been greater than 162 cm. Nagai and Sano have concluded that further investigation of ancient human remains from the southern part of the Korean peninsula is necessary in order to establish whether the regional differences seen in western Japan are the result of an improved diet associated with the appearance of rice or are the consequence of genetic combination with continental individuals. The limited nature of the sample must also be taken into consideration.

4. MATERIAL CULTURE

Technical studies on material culture remains from the Yayoi period have been carried out primarily on stone, ceramic, and metal artifacts, and the investigation which has been done has indicated a number of areas for future work.

In the Jōmon period, a chipped stone tool kit which included a variety of types of axe and adze tools as well as tanged knife scrapers, more conventional scrapers, drills, spearheads, tangless knives, and arrowheads remained in use virtually unchanged from the latter half of the Initial Jōmon period until Final Jōmon times (Hayashi 1967: 6). With the introduction of paddy rice cultivation and the subsequent reduction in certain Jōmon economic pursuits, the inventory of chipped stone tools became somewhat reduced; however, the chipped stone axe and adze tools and arrowheads from the Jōmon tradition continued in use into the Yayoi period, as did some varieties of chipped stone knives and scrapers (Okamoto 1966: 431). Polished forms of the axe and adze occurred back as far in time as the Early Jōmon period, but the Yayoi period sees the introduction of a number of distinctive,

continentally-derived forms which included a clam-shaped axe/adze, a single bevelled-edged adze, and a notched adze, as well as a very long type of polished stone arrowhead (some examples are 16 cm in length), polished stone spindle whorls, a double-edged dagger of polished stone, and the semilunar stone reaping knife which Watson (1971: 21) has termed "the hallmark of the Chinese Neolithic."

Analogue experiments on aluminum copies of the semilunar reaping knife have been carried out by Ishige (1968: 890-921) to determine the capabilities of this tool. The edge of this tool apparently was not sufficiently sharp to cut plant stalks but could be used in a manner by which rice kernels were removed from the stalk with a sharp twist of the wrist provided that the kernel clusters were not so ripe as to shatter when touched. With this method, the rice grains were collected in the hand. Because some of these knives show wear patterns around the holes, usually two in number, which are located near the curved back of the tool, it is thought that this tool was used in a manner similar to that of the Ainu *phipa*, a shell tool with wood fiber strings to attach it to two fingers of the hand by means of the two holes in the upper part of the shell. Ishige has built his case for the association of rice with this tool on the basis that the reaping technique described above is associated with rice harvesting in some parts of Southeast Asia. However, it should be noted that Ishige's conclusion cannot go unchallenged with regard to its use for harvesting rice only; for example, this type of knife was present at Yang-shao and Lung-shan sites in China where millet was the dominant cultivated cereal grain.

Some insight into manufacturing techniques for Yayoi period stone tools has been provided by the discovery of numbers of stone tools, both finished and unfinished, which are taken to represent workshop sites at Tateiwa (Kojima 1969; Takeshima, personal communication, 1972) and at Imayama, a mountain situated to the west of Fukuoka City which apparently was a source of stone for tool-making (Kanaseki, personal communication, 1975). Another site of Yayoi stone-tool manufacture was discovered near Lake Dainaka to the east of Lake Biwa at the Dainakanoko Minami site (Shiga Prefecture Ethnological Committee 1968: 34).

To date little other work on stone from Yayoi period sites has been undertaken. More investigation of rock outcrops within a reasonable radius of sites might yield useful data. Also, investigation of the actual techniques of polished stone manufacture, including débitage analysis, for this period has not been systematically carried out. Examination of the types of stone used for tools, both the properties of the types and the local sources, as established for the Fukuoka City area, would be useful.

With ceramic studies, considerable effort has been expended on the production of finer and finer ramifications of existing ceramic typologies. However, some technical studies of pottery have been undertaken. Sahara Makoto has written a number of articles dealing with certain aspects of Yayoi pot building, finishing, and decorating. Some of his more recent work concerns the method of pot construction in the Kinki region which centers on Kyoto, Osaka, and Nara. He has found that the earliest pottery of the Early Yayoi period was built in sections of rings with the joints, in many cases, fairly readily apparent on the vessel interiors. Sahara (1970: 28) has also argued that a pedestal type of turntable on which the clay rings were piled was used in this region beginning in the Early Yayoi period. He bases his

conclusion on the observation that, following a clockwise direction, the decorative bands show a definite connection between the starting and finishing points, and vessel necks show a very smooth horizontal finishing; in both cases, he argues that similar results could not have been achieved by the use of the hands alone. In this regard, it should be noted that the differences between hand and wheel techniques of pottery making are not as great as archaeologists once assumed they were; ethnographic studies have shown that a gradation of intermediate processes exists (Nicklin 1971: 48). As George Foster has noted, "I am inclined to believe that the commercialization of pottery-making is a function of a growing population and trade specialization, and that the presence or absence of the wheel in this process is purely fortuitous" (Foster 1959: 113). The Middle Yayoi period, especially in Kyushu, sees what some archaeologists argue is the mass production of large jar coffins; analogue experiments in addition to technical comparisons may provide some indications as to the feasibility of this suggestion.

No turntables or turntable parts have been discovered by archaeologists but, as in the cases of the kiln parts and crucible sherds which would have been associated with the local manufacture of bronzes in Japan but which have not been found at Yayoi site excavations, recognition may be the critical problem.

It is thought that Yayoi pottery was fired in open fires where it has been demonstrated that it is possible to attain the 600° to 800° C temperatures required for this particular quality of pottery. Black carbon deposits seen on some of the pottery of this period are, in part, attributable to pieces of plant material landing on the pots while they were undergoing firing (Sahara, personal communication, 1971). In pottery finishing, Sahara (1971, personal communication) has distinguished three methods of surface finishing for Yayoi pottery in the Kinki region: *hakeme*, horizontal brushing using a piece of wood, as can be ascertained from the imprint of wood grain present in some examples; *hera kezuri*, scraping of vessels presumably using some sort of spatula tool largely for thinning purposes, especially in the lower part of the body of the vessel; and *hera migaki*, polishing of vessel exteriors with a spatula type of tool, using vertical or horizontal strokes. In terms of pottery decorating, Sahara sees the turntable as having reached its peak of utility in the application of comb-pattern bands in the Karako III style of Middle Yayoi pottery in the Kinki Region. Ceramic studies of this sort are rare in Yayoi period research, and petrographic studies of thin sections of pots, bromoform analysis to determine tempering material(s), and hardness and porosity testing have yet to be applied substantively to the five major categories of Yayoi ceramic styles for comparative purposes.

The introduction of metallurgy into Japan during the Yayoi period poses a number of technical questions for the archaeologist. Bronze-working and iron-working technologies as well as artifacts were introduced from the continent to Japan where there is no evidence of any earlier experimentation with metallurgy. In the case of bronze, the continental imports included Western and Eastern Han mirrors, Chinese bronze coins, and Chinese weapons which include swords, *ko* halberds, and socketed and tanged spearheads. In addition, four mirrors termed *tachusaimonkyo*, double-buttoned mirrors with fine geometric designs which have been attributed by some archaeologists such as Kim Jeong-hak (1972: 162) to the general vicinity of present-day Liaoning Province, have been discovered at Yayoi sites.

On the basis of associated ceramic styles, the initial entry of these items into Japan is put at the end of the Early Yayoi period. Later in the Yayoi period, bronze bells, long and thin wide-bladed versions of the Chinese halberds and spearheads, bracelets, and disks thought to have served as shield attachments appeared at Yayoi sites, and for reasons to be discussed shortly are believed to have been cast in Japan.

The first question related to the introduction of metallurgy to Japan concerns the acquisition of the necessary knowledge of the constituent elements of the alloy and of the actual casting process. Independent development in Japan does not appear likely, especially in that no archaeological evidence of earlier stages of experimentation has been unearthed and in that this was a time period when contact with the metallurgically knowledgeable continent was present. The introduction of this technology by continental craftsmen after the initial appearance of continental metal items appears to be a more likely supposition. Operating on this assumption, the next question concerns the examination of possible sources of the constituent raw materials. Three alternatives are possible for the copper and tin required for bronze working: (1) the mining of native ores; (2) the importation of continental ores; and (3) the remelting of imported continental bronze artifacts.

There is no indisputable evidence of mining during the Yayoi period. Historic records refer to the mining of native copper during the Nara period and copper mines are known to have existed in antiquity in the Kinki and Chugoku regions. Both copper and tin mines were present in Oita and Miyazaki Prefectures in Kyushu, but whether these sources were tapped during the Yayoi period is not known (Tanabe 1962).

Importation of the required copper and tin from the continent is possible in that the ever-increasing use of iron in the Han dynasty might have meant that some supplies of these materials were available for trade to Japan. However, no archaeological or historical evidence in support of such trade has come to light.

The third possible source for the components of the bronze alloy, the remelting of continental bronze artifacts, can be tested chemically to some extent. If bronze has been remelted, it could be recognized in a decreased tin content because tin oxidizes at a lower temperature than copper. As Franklin (1975, personal communication) has noted, concentrations of oxides are sometimes seen in remelted metal although these might be the product of modern corrosion: a tendency toward a percentage increase in the trace elements might be observed in the remelted metal as well. The latter two observations would be apparent to the trained metallurgist.

To test the suggestion about the remelting of imported bronze artifacts, Tanabe (1962: 307) compared the chemical compositions of Japanese bronze bells which from his sample he classified as typologically older, Han dynasty mirrors, and continental swords and spearheads. He calculated that the maximum tin loss in remelting was 30 percent of the original content. While a few of the bells had a 15 percent tin content, the majority contained under 10 percent. The Han dynasty mirrors contained 25 percent tin, a finding that led Tanabe to conclude that these mirrors were not likely used; his conclusion was further supported by the differences in the associated lead contents for the Han mirrors and the Japanese bells. The tin content of the continental weapons was about 20 percent and the lead content between 5 percent and 16 percent. The lead content of the bells ranged from several percent to 10 percent; hence, it is concluded that the Japanese bells were probably

not made from remelted continental bronze weapons. Tanabe concludes that Korean weapons may have been used for this remelting process but he questions whether these weapons were present in the Kinki region, the center for the production of bronze bells in Japan. It would perhaps be wise for archaeologists also to take into consideration technical studies on Chinese coins in that their standardized compositions could possibly give a better indication of typical composition figures for continental bronzes. However, as Chase (1974: 148) has noted, the chemical composition figures for a bronze artifact can show rather surprising variations depending on the particular laboratory which carries out the tests. In his experiment, two ancient bronzes were ground to a powder which was thoroughly mixed before 500 mg of each were distributed to the various laboratories for the analysis of forty-eight elements. In the results from 21 laboratories, the coefficient of variance or relative standard deviation ranges from 4 percent for copper up to over 200 percent for some trace elements. Chase feels that some of this variation could be eliminated in the future through the determination of ranges and composition of unknowns and standard samples (1974: 184).

The accurate determination of types and quantities of trace elements is important in that ancient bronzes always contain some impurities, usually only as trace elements. The examination of trace elements has been undertaken to some extent in Japan in an effort to correlate bronze artifacts with ore bodies having similar trace elements. The analysis of impurities in the Tanabe study showed that there were no characteristic rare elements. However, Tanabe (1962: 302) has noted that zinc to levels of more than 0.003 percent was present in eight of the thirteen bronze bells analyzed. Although the data on micro-elements in Chinese samples is rather limited, the Komatsu and Yamauchi (Tanabe 1962: 302) analysis of ancient Chinese bronze mirrors indicates that zinc was present only in a few of the later samples, and the presence of zinc in the few Chinese swords analyzed by Chikashige is viewed by Tanabe as rather exceptional. Mitsukuni Yoshida has recently argued that the presence of zinc in some Japanese bronzes and in some Japanese ore bodies is evidence to suggest the use of local ores during the Yayoi period (Sahara and Kanaseki, personal communication, 1973). Tanabe (1962: 302) has cautioned that zinc is volatile because of its rather low boiling point (918° C) and that zinc contamination during burial is possible because zinc is a fairly common element in nature; however, in Franklin's opinion (personal communication, 1975), it is unlikely that zinc was transferred from the soil.

The question of whether bronze-casting could have been carried out independently of continental craftsmen is still open to further speculation; at the present time it appears more likely that experienced bronze-casters were involved in tutelary roles. To cast bronze requires the achievement and maintenance of temperatures of 900° C or higher. This knowledge of temperature comes in some cases, such as in Shang dynasty China, from experience in the firing of ceramics. However, the limited technical study on Yayoi ceramics (Sahara, personal communications) indicates that it is unlikely that Yayoi potters had knowledge of the production of temperatures high enough to melt the alloy and to produce crucibles hard enough to withstand the temperatures required for the melting process. There is some evidence to support the contention that continental craftsmen were involved in the early bronze-casting in Japan. Only one mould for a continental bronze artifact, that of a

narrow bronze sword (Kanaseki, personal communication, 1975), has been found in Japan. It is possible that this mould could represent a model made by a Chinese craftsman following the style of sword he was familiar with on the continent. It is unlikely that moulds would have been imported to Japan in view of their bulk; mould making could more easily have been relegated to Yayoi villagers who did have experience in stone-working. The fact that North Kyushu appears to have served as the initial focal point for bronze-casting in Japan with the production of the long and thin wide-bladed versions of weapons centered here is significant because of its geographical proximity to the Korean peninsula; plains in the central region of North Kyushu would have been relatively convenient locations for continental craftsmen to have begun teaching local villagers how bronze was cast.

It is difficult to attempt an explanation for the concentration of bronze-bell casting in the Kinki region beginning in the Middle Yayoi period. During this period, North Kyushu and the Kinki region were undergoing independent local cultural development as seen in ceramic styles and, to a lesser extent, in burial styles. How much contact existed between these two regions at this particular time is not clear, but it is known that both these areas were receiving mirrors from the continent and it is possible that bronze-casting could have been introduced directly into this region. It is also a possibility that continental craftsmen may have done some traveling in Japan; a travel route of sorts had been established along the Inland Sea during the Early Yayoi period when Yayoi culture was spreading eastward. The centralization of bronze-bell production in the Kinki region has been established not only on the concentration of bell finds in this and adjacent regions but also on finds of the moulds used in the casting of these bells. At Higashinara in Ibaraki City, Osaka Prefecture, a site occupied from Early Yayoi into Kamakura times, excavation in 1974 uncovered the remains of two Middle Yayoi burials, each surrounded by a square ditch, and a number of semisubterranean pit dwellings. The excavated materials found in association with these features included six types of stone moulds made of tufaceous sandstone for the casting of bells, ceramic replicas of bronze halberds, and moulds for the manufacture of comma-shaped beads. One of these moulds was complete; it is 43 cm long, 29 cm wide, 12.5 cm thick, and 28 kg in weight. The excavation did not uncover any evidence of a workshop area for bronze-casting. The location of the tufaceous sandstone used for the moulds was a 25 km² area to the northwest of the site; possible transport routes to the site could have been via Osaka Bay or via the Muko River (Tashiro, Okui, and Fujisawa 1975: 1-10).

As has been noted earlier, the absence of references to kiln parts in Yayoi period site reports can perhaps be explained by the fact that such parts are difficult to recognize and hence have been overlooked at sites; crucible sherds have not been reported either, perhaps due to recognition problems. It is also possible that continental craftsmen may have kept this important item for their craft with them when they departed.

Continental use of iron was well established by the time of the appearance of Yayoi culture in Japan. In the Korean peninsula as in China, agricultural development is seen as a major stimulus to iron-tool production; iron remains consist primarily of tools such as axes, sickles, and knives and are thought, according to Kie-duk Hwang (1964: 52) to have utilized the various iron ore deposits of the

peninsula. In Japan, iron made its first appearance at the Saitoyama shell midden in Kumamoto Prefecture in the initial phase of Yayoi culture. This piece of iron, which is 4.2 cm long, has the appearance of having blades on two sides, but it is presumed, although one part of the tool is missing, that one side served as a blade and the other was used for hafting (Otomasu 1972: 127). Photomicrographic and acidity testing studies carried out on this tool at Meiji University revealed that the iron was forged and not cast (Otomasu 1972: 127-128).

Other finds of wrought or forged iron have been made in Japan, and some larger artifacts such as iron weapons which are all probably of cast iron have been discovered as well, although this aspect of Yayoi period iron remains requires further clarification. From Iki Island, located in the Tsushima Strait between Tsushima and North Kyushu, at Haranotsuji, a site occupied from Middle to Late Yayoi times, came a wide variety of iron implements: ploughs, axes, sickles, picks, planes, perforators, fishhooks, and weights. These iron remains were found in association with iron bars which Okazaki (1956: 14-29; Mori 1970: 20) believes were brought from South Korea. The fact that iron remains have been unearthed at the Kimhae shell midden on the southeast coast of the Korean Peninsula is construed as evidence that iron-working technology was present in the southern part of the Korean Peninsula by about A.D. 100 (Mori 1970: 20). Indeed, Iki Island's proximity to the peninsula meant that the importation of iron bars would not have been too difficult a procedure. Iron weapons such as a sword from the Suku Okamoto site in Kasuga City, Fukuoka Prefecture, a *ko* halberd from the Tateiwa site, and a sword with a ring handle from the Haranomae site in Fukuoka City have been rather rare finds to date, and the general feeling among Yayoi period archaeologists seems to be that such items must have been imported from the continent. No moulds which can be unquestionably associated with iron-casting have been found, and while mould finds for bronze artifacts in Yayoi sites suggest bronze-casting in this period, it does not necessarily follow that iron-working technology was also introduced into Japan at the same time. Some Japanese archaeologists subscribe to the view that while iron artifacts were first used in the Early Yayoi period, local forging of iron did not begin until the middle part of the Middle Yayoi period. Hashiguchi (1974: 1-17) reports iron objects, including axes and arrowheads which he believes were locally forged; from the early part of the Middle Yayoi period at the Yoshigaura site near Fukuoka City.

It is very difficult to reconstruct the manner in which iron-working technology arose in Japan in view of the dearth of technical information on the rather small number of iron remains unearthed to date and poor state of knowledge of mining in antiquity in Japan. If iron were imported in the form of bars from the continent, it is certainly a possibility that Yayoi period villagers could have forged their required implements locally. In terms of possible sources of iron, Nishio (Tanabe 1962: 304) and later Yamamoto (1968: 97-109) have suggested that iron sands could have been used by early iron workers. Iron sands, which are primarily pure magnetite, are separated out in a manner very similar to gold panning. Iron sands form as a result of erosion in volcanically formed areas and are often found in riverbeds. Once recognized, iron sands could provide the essential raw material without the laborious tasks of locating and mining an ore deposit and then sorting and dressing the ore. However, the use of iron sands has not been verified, either

archaeologically or historically, for the Yayoi period. While archaeologists are now perhaps better attuned to the sorts of evidence associated with early metallurgy at archaeological sites, the research on currently available evidence such as materials thought to be slag from Yayoi sites has not yielded any conclusive results.

Much of the foregoing discussion on the application of technical studies to material culture has focused on some suggestions to indicate areas for future investigation. In all cases, technical studies will be of utmost importance to archaeologists interested in questions of production techniques for Yayoi period artifacts and the role of trade in terms of the acquisition of raw materials, the introduction of new technology, and the distribution of the finished products. Technical studies on other material culture remains, such as glass beads for which some stone moulds have been discovered, may further complement this picture.

CONCLUSIONS

In this paper I set out initially to examine the relationship between technical studies on materials from Yayoi period sites and archaeological interpretation of Yayoi culture. In what ways, then, have technical studies contributed toward attempts at archaeological explanation? Viewed in its proper cultural context between the egalitarian Jōmon culture, with its long tradition of hunting, gathering, and fishing, and the Kofun culture, in which status distinctions are demonstrated in the tumulus burials with their associated grave goods, the Yayoi period is clearly a time of transitional development in both economic subsistence patterns and sociopolitical organization. A number of continentally-derived cultural elements appear superimposed on the existing Jōmon cultural base and, while such technological advances as weaving and metallurgy were of unquestionable significance in determining the character of Yayoi culture, it appears at present that none had the impact that rice cultivation had on the society of that period and subsequent periods as well. In this connection, the successful intensification of rice cultivating practices to meet the requirements for cultural development in the latter half of the Yayoi period and in the following Kofun period is highly significant. At this time, the production of an agricultural surplus becomes more essential in view of the presumed appearance of individuals operating on at least a part-time basis in crafts such as metallurgy and of individuals of higher status who are thought to have been unavailable for full-time participation in agricultural activities. Past research on this question has involved the use of technical studies as outlined earlier. Future investigation into the labor inputs required of paddy rice cultivators today is necessary to allow estimates of the number of man-hours required during the Yayoi period for such activities. Estimates have not been possible to date because of differing views on the requirements of the rice plant (Grist 1968; Ito 1970; Mishima 1971; Nuttonson 1965; Zhukovskij 1950). Because very little research on soils has been utilized by Yayoi period specialists, it has not been possible, for example, to attempt to estimate the soil productivity of the Yayoi paddies or to note relationships between soil productivity and size of paddy field. A third area for future research concerns the problem of determining population concentration in the Yayoi period. Because so few Yayoi sites have been fully excavated, it has not been possible to attempt any realistic estimations of population figures for Yayoi period

sites. Some use of technical studies will be necessary to the investigation of these questions.

Another highlight of the development of Yayoi culture is the rapidity with which the diffusion of this culture took place. It appears that Yayoi culture met with little resistance as it spread eastward in western Japan. Even in eastern Japan, where the diffusion was not as rapid, this cultural complex appears to have reached northernmost Tohoku within four hundred years of its initial appearance in North Kyushu. To deal more rigorously with this question, archaeologists will need to make much more use of the various relevant dating techniques. In addition, technical studies on material culture remains may pick up subtle differences in the cultural complex, particularly in ceramics, as it moved eastward.

Also important in terms of the highlights of Yayoi culture development are the effects of the florescence of Yayoi culture in the Kinki region on the subsequent Kofun culture of that area. While Early Kofun tombs of the fourth century A.D. were distributed from Kyushu to Kanto, the development of tombs was centered in the Kinki region, as was cultural development for the most part in the Middle and Late Yayoi periods. Although external influences resulting from an intensification of the continental interaction begun in Yayoi times are apparent in Kofun culture, cultural continuity from the Yayoi period was also a significant component of this cultural complex and, in this regard, the influence of the mound burial surrounded by a square ditch with associated burial goods was a significant factor in the development of the burial complex so characteristic of Kofun culture. Technical studies may be useful in determining the extent of the contribution of Yayoi period technology, especially metallurgical, to Kofun culture. In the Kofun period, iron production became more widespread and attained a fairly large scale in order to fulfill not only the requirements of expanding cultivation but also those of military activity. The use of bronze for decoration continues in Kofun times with the appearance of a number of new forms.

The need for more technical studies in all the areas outlined is obvious. The applicability of these techniques has been dealt with in terms of major cultural developments during the Yayoi period. Methodological studies inevitably lead to some revision and even rejection of past hypotheses about cultures. Each year in Japan, new physical and chemical analytical methods are being applied to old archaeological problems, and new types of archaeological materials are investigated by established analytical methods. It would seem reasonable to conclude that technical studies will play an ever-increasing role in archaeological interpretation of Yayoi period Japan. The applications of technical studies to the present time have fairly clearly indicated the utility, as well as the shortcomings, of these techniques in dealing with questions of cultural interpretation for this period.

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